# Importance and Utilization of the Genetic Resources of Cultivated Species

*Universidad Nacional Agraria La Molina*

*50th Anniversary of the Escuela de Post Grado*

*"Research for a Sustainable Development"*

*September 16-17, 2008*

**Candice Gardner, USDA-ARS, Ames, IA**

USDA ars

NCRPIS
Providing Plant Genetic Resources for Agricultural Success
AMES, IOWA

**Food security depends upon germplasm collections.**

http://www.fao.org

**In agriculture, the most important resources are soil, water, air, and germplasm collections.**

Science 1986

**Plant genetic resources (PGR) have been utilized over the millennia to improve the human condition. Development of crops that provided stable supplies of food, feed, fiber and fuel offered alternatives to nomadic existence, and enabled societies to develop and flourish around the world.**

**The development of improved crops and cropping systems, and the increased availability of materials essential for sustenance, growth and development**

**made possible the rapid evolution of human intellectual capacity, discovery and invention. As a result, the nature of human society and human behavior changed.**

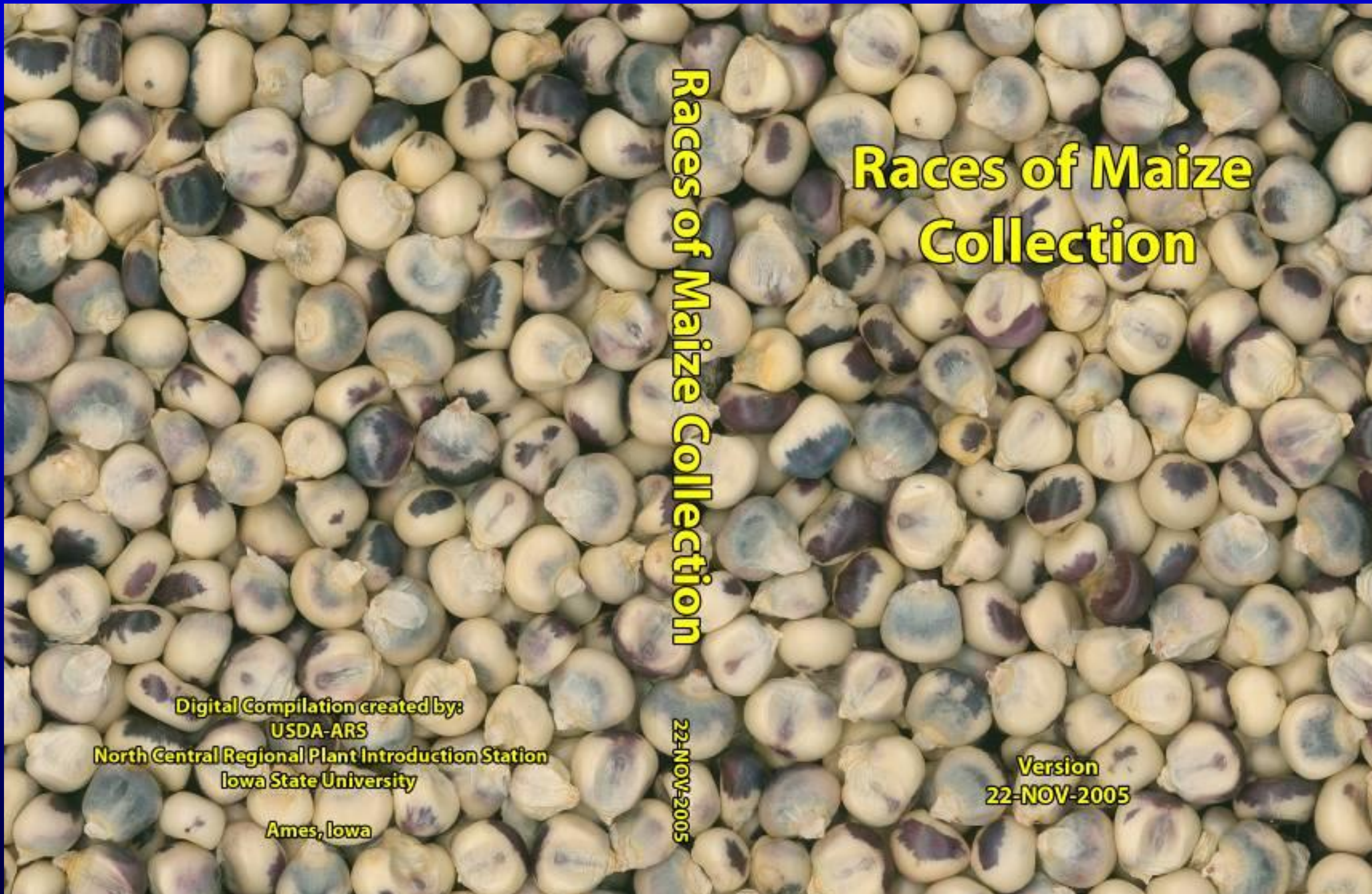
**Conservation and utilization of PGR have made possible the continuous varietal improvement necessary to provide solutions for agricultural production challenges, the development of new crops and new uses, and improvements in health and nutrition.**

**Growing global energy needs coupled with the increasing demands for food and other plant-based resources have highlighted the critical importance of PGR now more than ever. Demand for well-documented PGR increases annually.**

# The Four F's

- Food
- Feed
- Fiber
- Fuel

The World’s #1 Crop


Races of Maize Collection
Races of Maize Collection
Version
22-NOV-2005
22-NOV-2005
Digital Compilation created by:
USDA-ARS
North Central Regional Plant Introduction Station
Iowa State University
Ames, Iowa

The Other World's #1 Crop

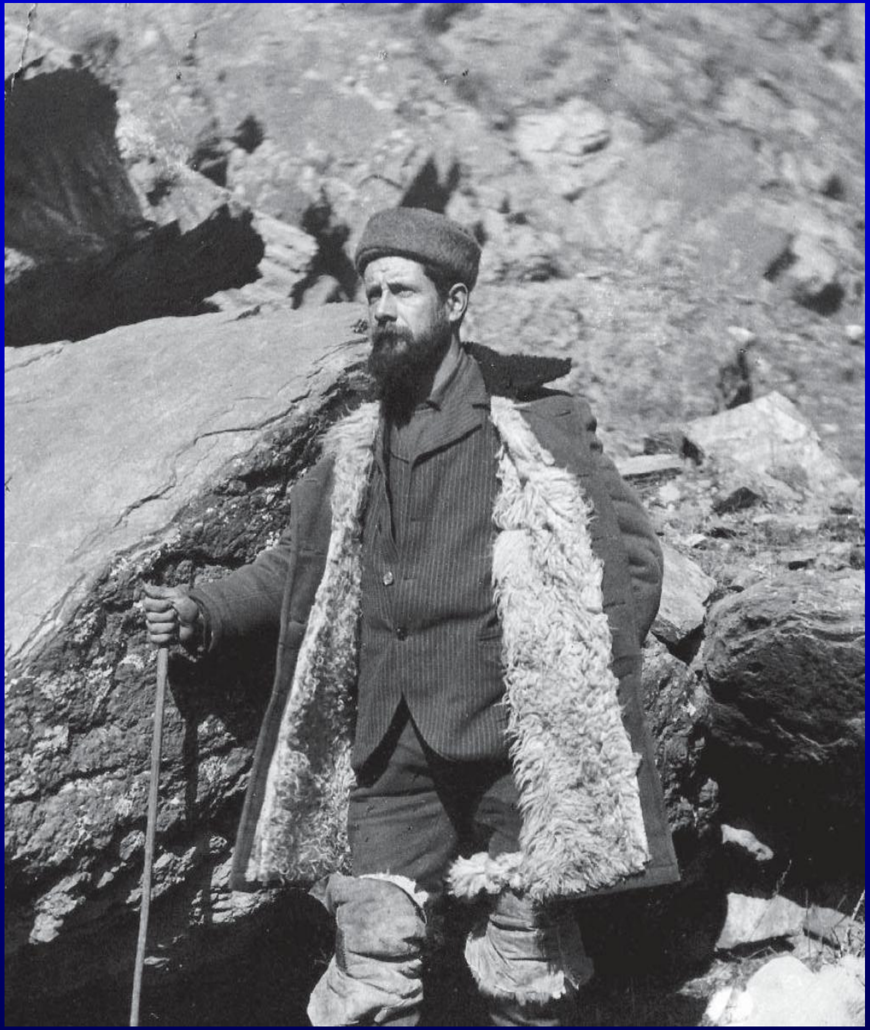
Grapes in Washington State, USA

# Soya in Brazil

**Courtesy of Luciano Nass, EMBRAPA**

# The Early Plant Explorers

**Nikolai I. Vavilov** is recognized as the foremost plant geographer of contemporary times. To explore the major agricultural centers in this country and abroad, Vavilov organized and took part in over 100 collecting missions, including those to Iran (1916), the United States, Central and South America (1921, 1930, 1932), the Mediterranean and Ethiopia (1926-1927). He and his colleagues were the first to thoroughly collect potato germplasm in the Andes.



1910, the Office of Foreign Seed and Plant Introduction of the United States sent **Frank N. Meyer**, one of world's most outstanding collectors, to the Sinkiang Province of China. He was also to go to Europe, Russia, and Tibet. During 1910 to 1911, Meyer explored Irkutsk, Kashgar, Yarkand, and from there to Ak-Suand and on to Kul'dzhe, always in search of hardy crop plants and their wild relatives that could tolerate abiotic stresses.

# Potato Germplasm Collection Development

**The dedication and effort of pioneer taxonomist Carlos Ochoa formed the foundation of the CIP-held collection of potato genetic resources. This Peruvian scholar, whose crusade to find wild species in the Andes began more than 40 years ago, has discovered 80 different species—about one-third of all the wild potatoes known to exist.**

http://www.cipotato.org/potato/


**Drs. Salas & Spooner**
**Collecting Wild Germplasm**


**"THE DISAPPEARANCE OF OLD VARIETIES, the landraces of crop plants, and their wild progenitors could eventually be recognized as the great sleeper issue in the last decades of the 20th century.**

**It is difficult for us to visualize a scenario more profound in its implications, yet less appreciated by funding institutions, governments, and the general public, than that entailed in the mass elimination of a large number of plant species that has taken place and continues to take place in the centers of their diversity."**

**(Qualset and Shands, 2005).**

# Recent Threats to Global Food Production

- Insect and Disease Pests
  - Wheat Stem Rust Reemerges
- Fertility Costs and Availability
- Energy Costs
- Water
- Stable Supply of Adapted Cultivars
- Land Use / Land Loss

# Plant Germplasm Collection Development Today

- Collection expeditions
- Germplasm originators

- Exchange between institutions
  - Within National Institutions
  - Between Nations, governed by the ITPGRFA

# Successful Conservation & Utilization of PGR Depends On:

- Targeted acquisition
- Documentation
- Effective maintenance and regeneration programs
- Thorough evaluation and characterization
- Effective use of associated information
- Distribution of PGR to research communities

# Last but not least…

- Pre-breeding activities to facilitate utilization.

- Thorough understanding of the phenotypic and genetic variability of a crop and its wild relatives, their adaptation, life forms, breeding systems, traits and biological properties supports PGR conservation activities, and is essential to realize their potential for contribution.

# Current Status: Plant Genetic Resources

- An estimated 6 million samples in genebanks world-wide; of these, 1.5 million are probably unique.
- About 10% of the samples are held by the IARCs.
- Most samples are in genebanks controlled by national governments.
- Large national genebanks in the U.S., Canada, Australia, Japan, S. Korea, India, China, Brazil, Russia, Germany, South Africa.
- Public gardens, NGOs, universities, and companies also hold thousands of samples.

**The Global Crop Diversity Trust is an independent international organization which exists to help ensure the conservation and availability of crop diversity for food security worldwide. It was established through a partnership between the United Nations Food and Agriculture Organization (FAO) and the Consultative Group on International Agricultural Research (CGIAR).**

# Annex 1 Crops of the ITPGRFA

The crops listed include: breadfruit, asparagus, oat, beet, brassicas (the cabbage family including broccoli and cauliflower), pigeon pea, chickpea, citrus, coconut, aroids (including taro and cocoyam), carrot, yams, finger millet, strawberry, sunflower, barley, sweet potato, grass pea, lentil, apple, cassava, banana/plantain, rice, pearl millet, beans, pea, rye, potato, eggplant, sorghum, triticale, wheat, faba bean, cowpea, maize and more than 80 forage species from 30 different genera.

# The U.S. National Plant Germplasm System (NPGS)

- “Base collection”; preservation research.
- GRIN database: www.ars-grin.gov
- Acquisition via plant exploration and exchange .
- Germplasm quarantine activities now part of APHIS; ARS conducts related research.
- 26 active US sites manage clonally and seed-propagated collections.
- Conduct associated research.
- Crop Germplasm Committees; university, NGO, industry cooperators, and ARS.

## National Plant Germplasm System

# Types of germplasm

- Wild crop relatives
- Landrace collections
- Genetic stocks
- Domestic breeding lines
- Heirloom accessions
- Cultivars
- Plant mycosymbionts

# US Regional Plant Introduction Station Functions

- **Conserve Plant Genetic Diversity.**

- **Encourage Use of Germplasm.**
- **Conduct Research to Improve Genetic Resource Management Programs.**
- **Generate Information to Better Target Germplasm Use by the User Community.**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# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

**Acquisition**

**Documentation**

**Maintenance & Regeneration**

**Characterization**

**Evaluation**

**Distribution**

# Germplasm collection now utilizes GIS technology

**Participants in a 2001Kazakhstan expedition:**

**Richard Hannan**

**Stephanie L. Greene**

**Alexandr Afonin**

**Nickolai Dzubenko**

# Institutes involved

- **USDA, ARS National Plant Germplasm System**
- **Kazakhstan Institute of Agricultural Science- Aral Sea Experiment Station**
- **N.I. Vavilov Institute of Plant Industry, Russia**
- **University of St. Petersburg, Russia**

# Results

- **Trip covered 1180 km (~ 730 miles)**
- **Collections were made at 89 sites**
- **432 accessions were collected:**
  - **138 *Medicago***
  - **86 Legumes (*Astragalus, Vicia, Lathyrus, Trifolium*)**
  - **48 Grasses**
  - **58 Wild onions (2-3 species)**
  - **102 Other horticulture (wild forms of hops, medicinal species, lettuce,ornamentals, cultivated garlic, apples)**

# *Hypericum* Collection in the Ozarks

# Wild *Helianthus* Collection in California

# US NPGS System Holdings

- 26 Active Sites + the NCGRP (Ft. Collins) + the NGRL
- 33 Designated Collections
- 508,622 Accessions as of September 13, 2008
- 20-25% of Accessions Distributed Yearly
- 2,126 Genera; range of 1-583 per site
- 13,111 Species; range of 1-3,058 per site
- 235 Families Represented

# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

Acquisition

**Documentation**

Maintenance & Regeneration

Characterization

Evaluation

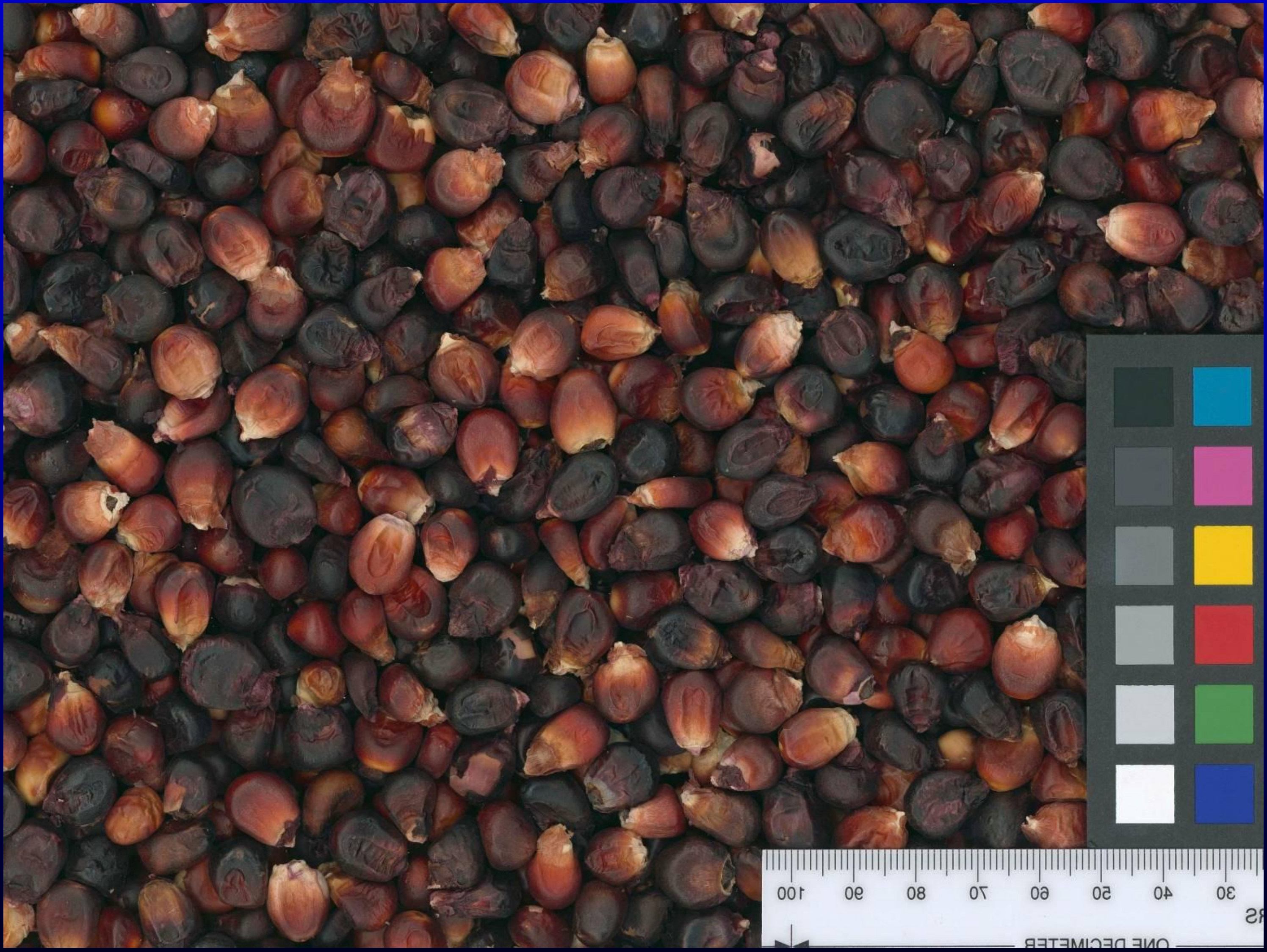
Distribution

# Crop Evolution Lab Records



| | | | |
|---|---|---|---|
| 4736 | Panicum hirticaule | deWet 4349 | 4.5 miles south of Ahuacatlan and 2.7 mi. south of Jala turnoff along Mex. 15 in Nayarit State. |
| 4737 | Panicum sonorum | deWet 4362 | 1 miles southeast of Ciudad Obregón along Mex. 15 in Sonora State |
| 4738 | Panicum sonorum | deWet 4365 | 11 miles east of Navojoa along Alamos road Sonora, Mex. |
| 4739 | Panicum sonorum | deWet 4366 | " " |
| 4740 | Panicum sonorum | deWet 4367 | " " |
| 4741 | Panicum sonorum | deWet 4373 | 20.4 miles N.W. of Alamos and 13.6 miles E of Navojoa, Sonora, Mex. along the Alamos Road |
| 4742 | Panicum sonorum | deWet 4374 | 23 miles NW of Alamos and 11 mi. East of Navojoa, Sonora, Mex. along Alamos Rd. on eastern side of Cerro Prieto |
| 4743 | Panicum sonorum | deWet 4375 | 23 miles N.W. of Alamos, Sonora, Mex. along road to Alamos past base of Cerro Prieto. |
| 4744 | Panicum sonorum | deWet 4400 | among Ruins de Ixtlán. 2.7 mi. SE of little town of Ixtlán del Rio Nayarit. |
| 4745 | Panicum sonorum | deWet 4401 | 2.7 mi. SE of Ixtlán del Rio, Nayarit just off Mex. 15. |
| 4746 | Panicum sonorum | deWet 4402 | 11.5 mi. east of Ixtlán, Nayarit in Jalisco along Mex. 15. |
| 4747 left out. 4748 | Panicum sonorum | deWet 4405 | 15.4 mi. SE of Tequila and 1.7 from El Arenal, Jalisco along Mex. 15. |
| 4749 | Panicum stramineum | deWet 4353 | 3.3 mi. south of Oasis de los Chinos + 57.8 south of Santa Ana in Sonora State, Mex. |
| 4750 | Panicum stramineum | deWet 4385 | 13.2 mi. SE of Escuinapa and 66.8 of Mazatlán, Sinaloa, along road, Mex. 15 |
| 4751 | Panicum stramineum | deWet 4388 | 78.3 mi SE of Mazatlán and 24.7 mi SE of Escuinapa along Mex. 15 to Tepic |
| 4752 | Panicum adspersum | deWet 4415 | 8 mi. N. of US 77 + US 83 junction in Harlingen, Texas |

# Acquisition of Images




G 32373
(cm)
(cm)

# Genebank Information Databases

A major function of a genebank is to manage the information associated with collections and provide them in a usable format, both for collection management and to facilitate utilization.

Examples of germplasm information databases would include GRIN, SINGER, and EURISCO, among others.

- **Information associated with the collections increases their value to researchers and to genebank managers, enables better targeting to meet research objectives.**
- **Automation of data collection and transfer activities improve genebank resource use efficiency.**
- **IT and IM Tech transfer between sites and between researchers is increasingly critical for successful germplasm conservation and utilization.**
- **Interoperability with genomic databases is a *high priority***
- **Stakeholder input is key to the future utility of PGR information delivery systems.**

# Use of Existing Information to Assist in Collection Development Strategies

too much information can be overwhelming…

not enough

Readily accessible, useful information is enabling

# GRIN-Global

**GRIN-Global is a project whose mission is to create a new scalable, version of the GRIN system suitable for use by any interested genebank in the world. It is being developed in a joint effort with the Global Crop Diversity Trust, Bioversity International, and the Agricultural Research Service of the USDA. Replacement of the current GRIN system for NPGS use with the GRIN-Global system is scheduled for the last quarter of 2010.**

http://cool.ars-grin.gov/wiki/index.php/Main_Page

http://cool.ars-grin.gov/gringlobal/forums/

# Project Goals

- To provide the world's crop genebanks with a powerful, flexible, easy-to-use global plant genetic resource (PGR) information management system that will constitute the keystone for a sustainable, rational, efficient, and effective global network of genebanks to permanently safeguard PGR vital to global food security, and to encourage the use of PGR by researchers, breeders, and farmer-producers.

- **The database and interface(s) will be designed to accommodate both commercial and open-source programming tools, to be database-flexible, and to require no licensing fees for genebank use. This will enable institutions with limited IT resources, as well as better-supported genebanks, to adopt GRIN-Global. The database will be deployable on local stand-alone computers at sites with limited computational capabilities, as well as at networked sites.**

# Genetic resources flow chart

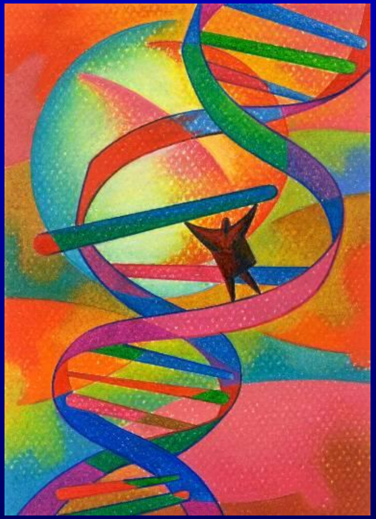
Accession in genebank

Morphological data

GRIN

Passport
Data, GIS

Phenotypic data
Disease
Nutrition
Yield components



Genotypic data

Accession Utilization

C. Coyne, Pullman, WA

# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

Acquisition
Documentation
Maintenance & Regeneration
Characterization
Evaluation
Distribution

# The objective of Maintenance and Regeneration is to provide high quality seed and plant materials which are true to the original genetic profile.

# Viability & Preservation Research

- The main research efforts in this area within the USDA are conducted at the NCGRP in Ft. Collins, CO, but also at several other sites.
- Lipid chemistry is known to impact effective storage practices.
- Cryopreservation techniques are being successfully developed for woody species; apple, willow, and ash are recent examples.
- Tissue culture is essential to both micro-propagation of species such as strawberry or potato; it also provides for resolution of some phytosanitary issues.

- **Controlled pollination is necessary for cross-pollinated crops, and is accomplished by hand- or insect-mediated methods.**

- **Clonal and micropropagation methods require controlled conditions for the production of pathogen-free propagules**

- **ALL CONTAMINATION IS BAD, REGARDLESS OF THE SOURCE**


PI
578603
Dactylis
glomerata
Cyprus

Phaseolus regeneration in Pullman, WA


23

# Seed Storage at the National Small Grains Collection, Aberdeen, ID

# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

Acquisition

Maintenance & Regeneration

Characterization

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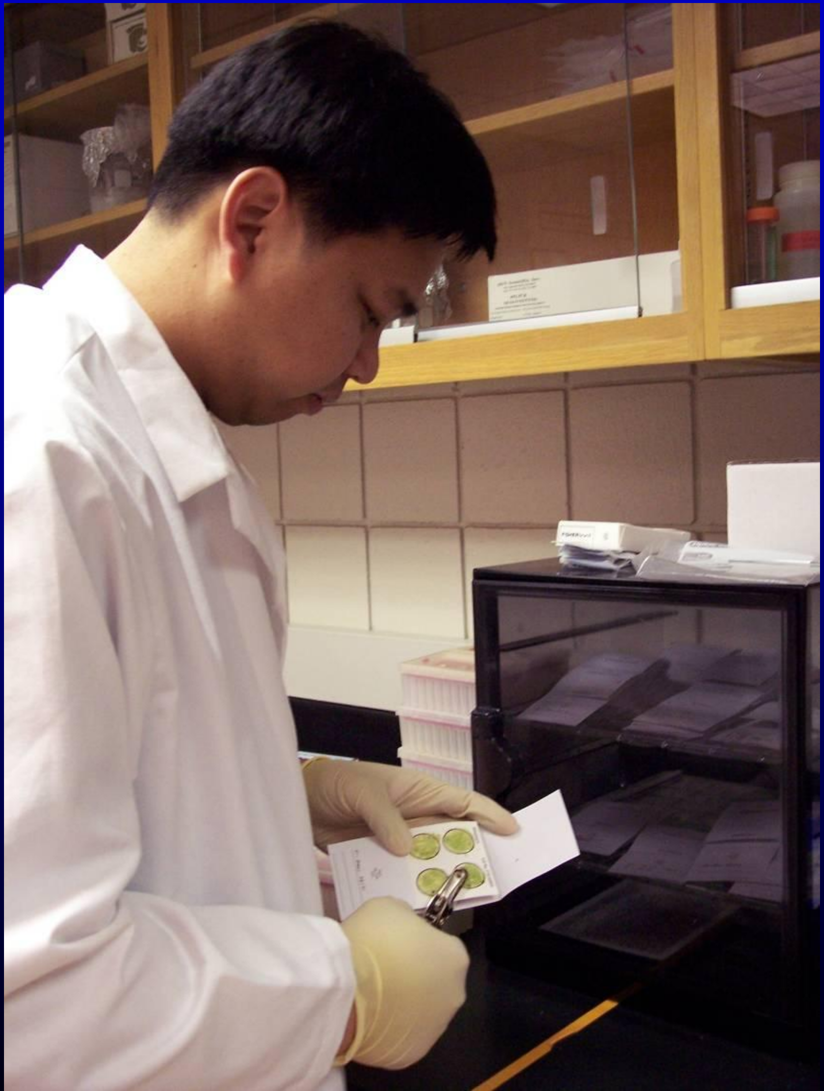
# Use of DNA Capture Cards for Molecular Characterization of Collections

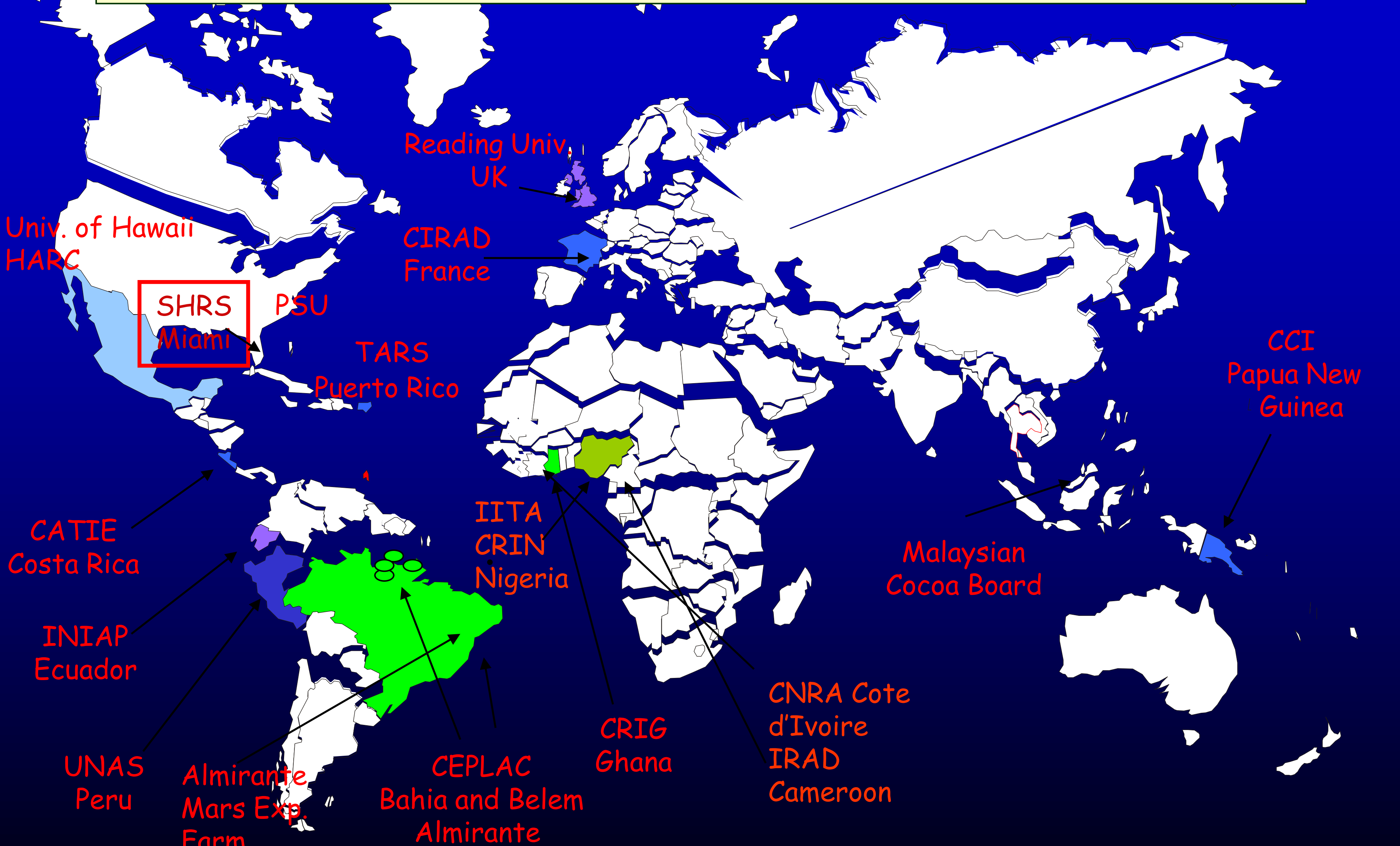


# Sequencing, annotation, and database management of the genome of *Theobroma cacao*

- **A composite linkage map from the combination of three crosses made from commercial clones of cacao, *T. cacao* L.** Tropical Tree Genomics and Genetics. DOI 10.1007/s/2042-008-9011-4. Brown J. Steven Brown, Robert T. Sautter, Cecile Olano, James W. Borrone, David N. Kuhn, and Raymond J. Schnell. 2008.

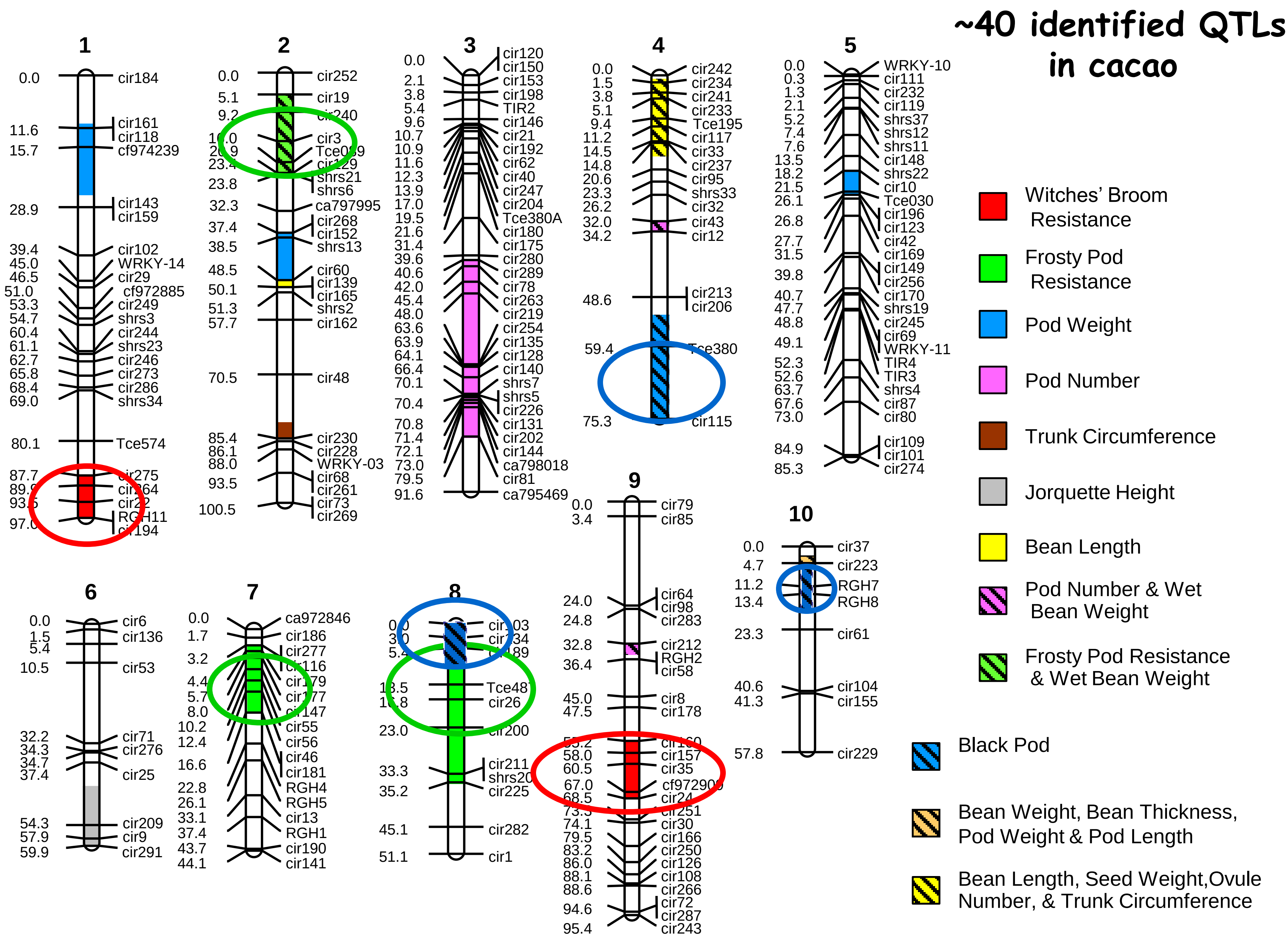
- **Development of a Marker Assisted Selection Program for Cacao.** Phytopathology Vol 97, No 12, 1665-1669. Schnell, R. J., D. N. Kuhn, J. S. Brown, C. T. Olano, and J. C. Motamayor. 2007.

# SCA and other formal and informal collaborative projects for cacao breeding and genomics



# Current field evaluations

| Research Stations | Genotypes |
| --- | --- |
| **South and Central America** | |
| CATIE, Costa Rica | 4,000 |
| INIAP, Ecuador | 12,500 |
| MARS Farm Almirante, Brazil | 4,500 |
| IBE, Peru | 500 |
| **West Africa** | |
| CNRA, Cote d'Ivoire | 1,500 |
| CRIG, Ghana | 5,000 |
| CRIN, Nigeria | 500 |
| IRAD, Cameroon | 300 |
| **Asia** | |
| CCI, PNG | 2,000 |
| **USA** | |
| Miami (quarantine and nursery) | 250 |
| Mayaguez (germplasm collection) | 350 |
| Hawaii (selection on Oahu and Hawaii) | 1,600 |
| Total genotypes for project | 33,000 |


~40 identified QTLs in cacao
Witches' Broom Resistance
Frosty Pod Resistance
Pod Weight
Pod Number
Trunk Circumference
Jorquette Height
Bean Length
Pod Number & Wet Bean Weight
Frosty Pod Resistance & Wet Bean Weight
Black Pod
Bean Weight, Bean Thickness, Pod Weight & Pod Length
Bean Length, Seed Weight,Ovule Number, & Trunk Circumference

## Number of plants with the favorable alleles for disease resistance at the two QTL for WB and three QTL for FP in families currently under evaluation at CRIG in Ghana.

| Family | n | WB | BP | WB+BP |
|---|---|---|---|---|
| T85/799x SCA6 | 79 | 19 | 6 | 2 |
| N8/122 x SCA6 | 90 | 28 | 19 | 6 |
| SCA6 x NA34 | 109 | 34 | 11 | 6 |
| T63/967 x SCA6 | 119 | 11 | 1 | 0 |
| T63/971 x SCA6 | 15 | 4 | 2 | 1 |
| | 412 | 96 | 39 | 15 |

## Where are we going next?

**The development of SNP markers in genes involved wi**
**disease resistance, productivity, and quality.**

**To do this we need to sequence the genome and produc**
**physical map to complement the genetic linkage map.**

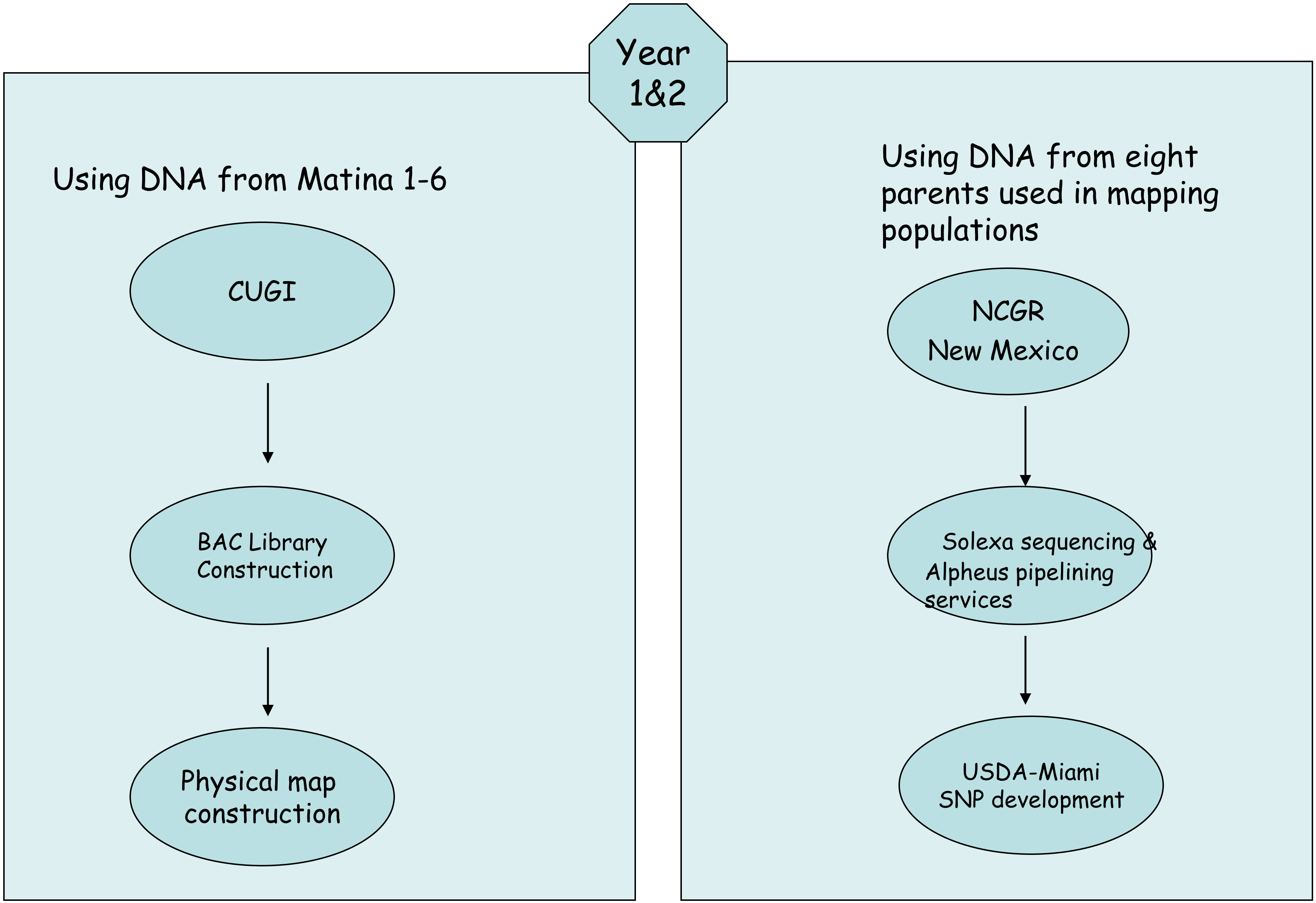
**The MAS breeding program would be greatly enhance**
**accelerating the delivery of improved, productive, dise**
**resistant cultivars to cocoa farmers.**

Choice field location on Kona side of Hawaii

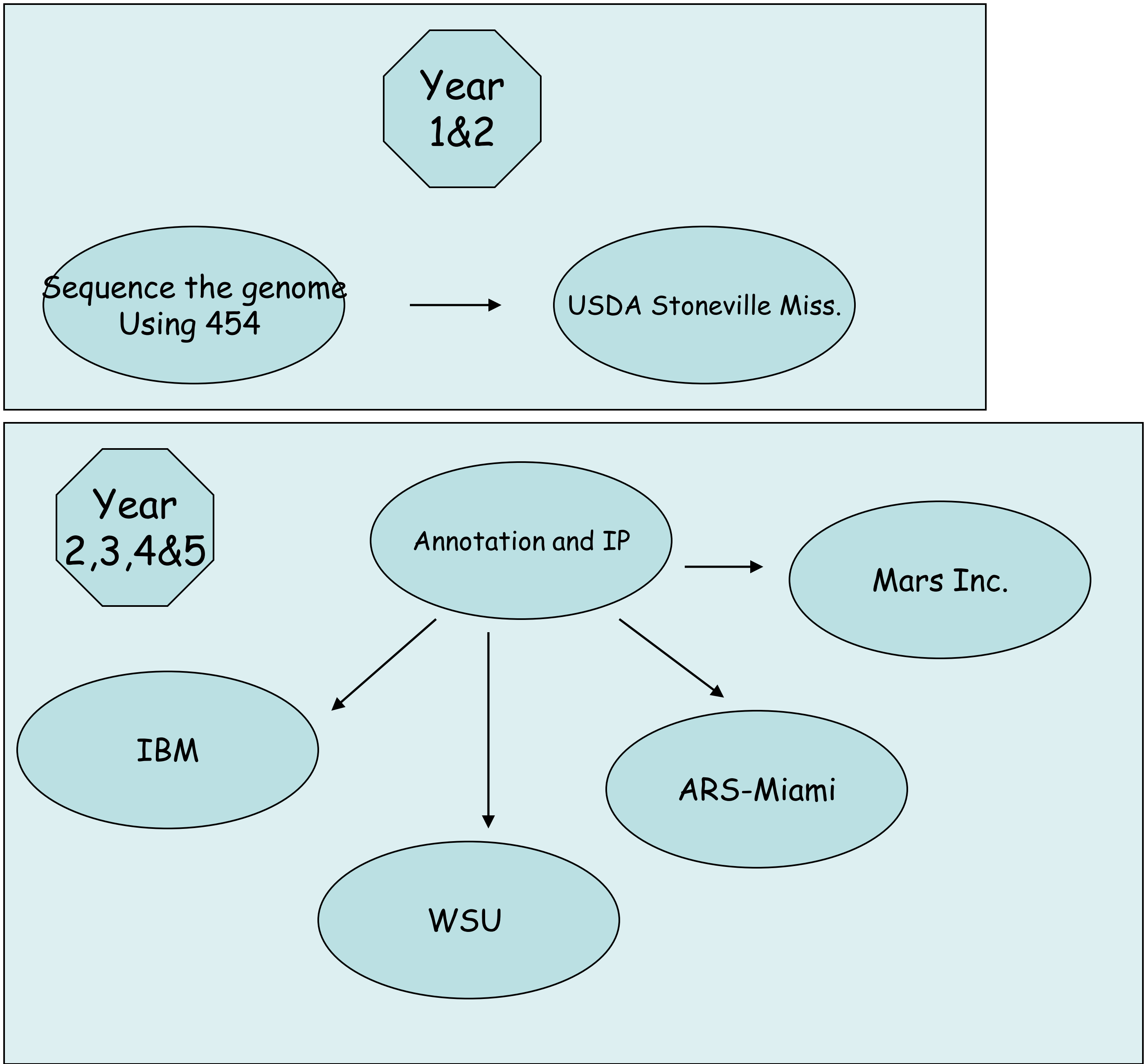
# Sequencing the *T. cacao* genome

| Species | Genome size |
|---|---|
| Yeast | 12 Mb |
| *Arabidopsis* | 119 Mb |
| *Theobroma cacao* | 415 Mb |
| Rice | 430 Mb |
| Dog | 2,400 Mb |
| Human | 3,300 Mb |

# Whole genome sequencing workflow



# Whole genome sequencing workflow



# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

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# Adaptation Criteria

# Ames in the Wintertime

# Ames, IA in the Summertime

# 50% Highland Tropical Maize –

# Unadapted to the MidWest

# GEM Project Has Successfully Introgressed

# Exotic Germplasm –

# 190 Lines Released with Adaption to the Midwest or Southeast

# Activities of the NPGS Integrate Data Acquisition to Enhance their Efficiency and Collection Value

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# CRIS Project Search for US - NCR

A search of the Cooperative Research Information System (CSREES and ARS Projects) resulted in identification of 528 projects using plant genetic resources on September 4, 2008.

1,459,816 samples were distributed by the NPGS from 2000-2006, or an average of 25% of collection holdings annually. Between 30 and 40% were distributed to international recipients.

***Next three slides courtesy of Luciano Nass, EMBRAPA-Labex USA***

# BRAZIL – SUGARCANE in 2008

## (1,000 tons)

| TOTAL | SUGAR AND ETHANOL INDUSTRY | | | OTHERS |
|---|---|---|---|---|
| | TOTAL | SUGAR | ETHANOL | |
| 710,280 | 558,720 | 240,890<br>43% | 317,830<br>57% | 151,560 |

Source: CONAB, 2008

# BREEDING AND GENETIC ENGINEERING

- Sugarcane varieties = interspecific hybrids
  - Introduced to Brazil 14th century
  - Complex genetically (2n = 70-120) with large DNA content.


*Saccharum officinarum*
(2n = 80)


*Saccharum spontaneum*
(2n = 40-128)


*Saccharum robustum*
(2n = 60-205)


*Saccharum barberi*
(2n = 111-120)

# BREEDING AND GENETIC ENGINEERING

- Historically Brazil has had an intensive sugarcane breeding program
  - 550 varieties developed to date
  - 51 varieties released since 1995
  - 20 varieties account for 70% of total planted area

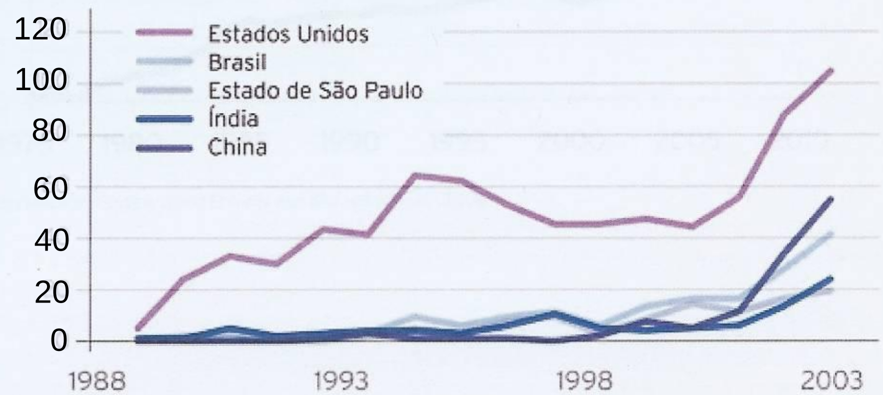
- Sugarcane Genome Project

  (http://sucest.cbmeg.unicamp.br/en)

  - Understand commercial cultivar origin
  - Identification of diversity and genetic variability
  - Introgression and QTLs identification (Quantitative Trait Loci)
  - Diagnostics for disease resistance / tolerance
  - Structural and functional genomics

## Number of published papers on sugarcane


## Number of published papers on ethanol extracted from biomass




**Source: Fapesp (2008)**

# Early Guayule Production for Natural Rubber



**Courtesy of Terry Coffelt, USDA-ARS, Maricopa, AZ**

# Guayule – A Commercial Crop for Production of High quality, Natural Rubber Latex for Hypoallergenic Products

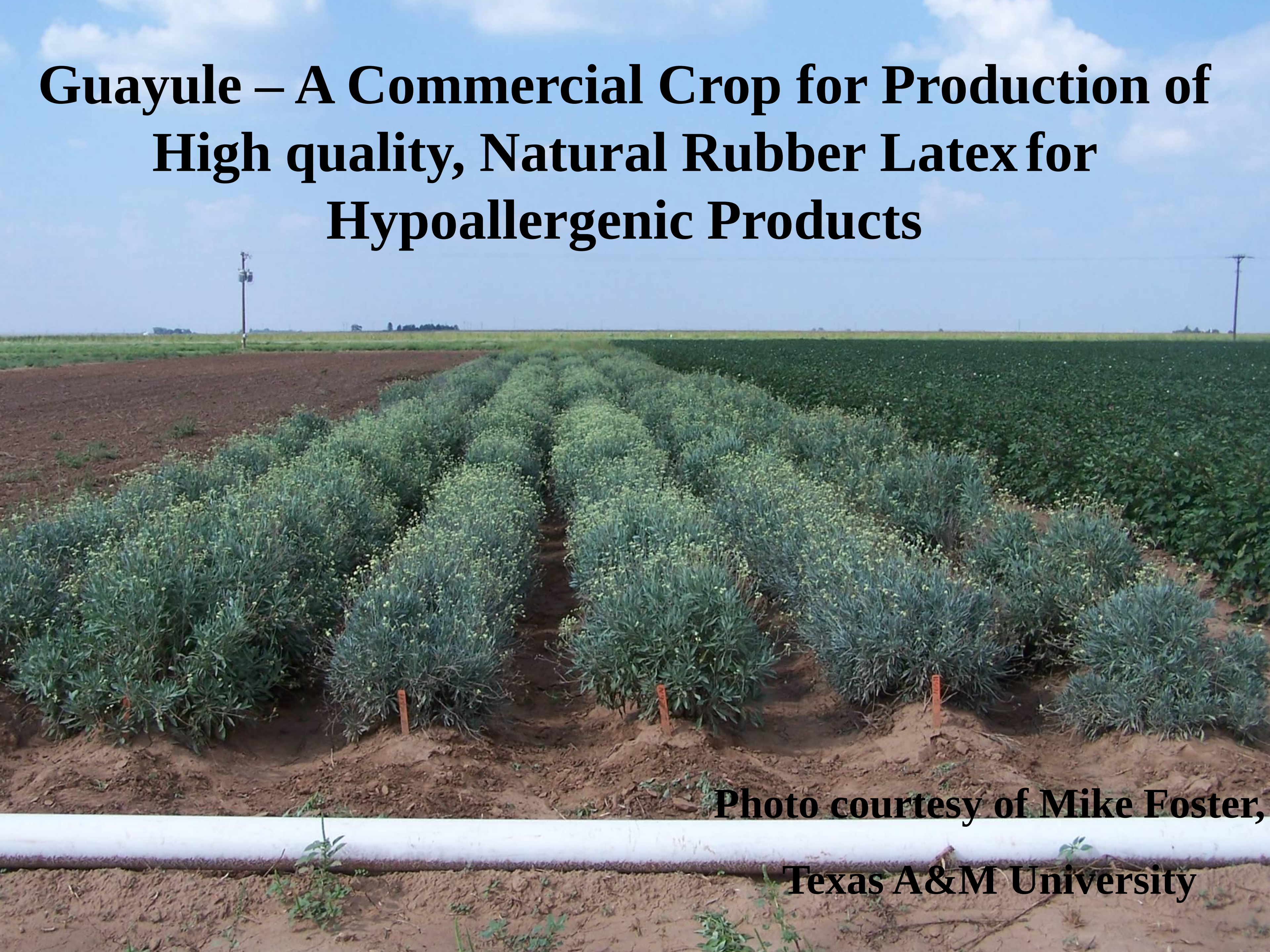


Photo courtesy of Mike Foster,

Texas A&M University

# The *Zea nicaraguensis* Saga


MEXICO
BELIZE
Caribbean Sea
San Pedro Sula
GUATEMALA
Guatemala
HONDURAS
Santa Ana
San Salvador
EL SALVADOR
NICARAGUA
Leon
Pacific Ocean
COSTA RICA
San Jose
PANAMA


PI 615697
05ncaim 1
GH3
227 plants
PI 615697
05 ncaim 1
GH 3
227 plants
PI 615697
05 ncaim 1
GH 3
227 plants

# Education for a Sustainable Future